EPA/540/2-89/015

SUPERFUND TREATABILITY CLEARINGHOUSE

Document Reference:

GA Technologies, Inc. "PCB Destruction Facility Circulating Bed Combustor." Technical report prepared for U.S. EPA. 24 pp. December 1985.

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SUPERFUND TREATABILITY CLEARINGHOUSE ABSTRACT

Treatment Process:	Thermal Treatment - Circulating Bed Combustion (CBC)
Media:	Soil/generic
Document Reference:	GA Technologies, Inc. "PCB Destruction Facility Circulating Bed Combustor." Technical report prepared for U.S. EPA. 24 pp. December 1985.
Document Type:	Contractor/Vendor Treatability Study
Contact:	Hiroshi Dodohara Ogden Environmental Services, Inc. P.O. Box 85178 San Diego, CA 92138-5178 619-455-2383
Site Name:	Gulf Oil Corp., Berkley Heights, NJ (Non-NPL)
Location of Test:	Berkley Heights, NJ

BACKGROUND: This treatability study reports on an evaluation of a pilot-scale, transportable, circulating bed combustor (CBC) for the incineration of PCB contaminated soils. This May 1985 test was for a demonstration to support a permit application for operation in California.
OPERATIONAL INFORMATION: The CBC demonstration utilized a spiked soil (10,000 ppm PCB concentration) at a feed rate of 400 pounds per hour and a CBC operating temperature of 1800^{o}F. No information was provided on the soil. Three four-hour runs were completed; however, because problems occurred in the sampling of particulates in the initial test, a fourth abbreviated run of two hours was conducted solely for collecting a particulates sample. Three supplementary runs were conducted to evaluate low combustion temperatures (1625^{o}F) and to incinerate PCB-contaminated soil. Feed soil, fly ash, and bed ash were sampled and analyzed. Stack emissions samples were collected for particulates, semi-volatile organics, and volatile organics.
PERFORMANCE: Destruction Removal Efficiencies (DREs) ranged from 99.9999% to 99.995% for PCB except for 1 run which resulted in a 99.82% efficiency. No significant PCB stack emissions were indicated. Particulate stack emissions during one test did not meet the standard for stationary air point sources. High particulate emissions were attributed to a high process air supply inadvertently applied to the air bag filtration unit. Another significant test value was the residual dioxin and furan in the treated soil. High values of 1.33 ppb for dioxins and furans were indicated in the fly ash.

Several operational problems were reported. The damp, irregularly shaped soil feed material used during the trials clogged the transfer ducts in the unit. Agglomeration of the soil also occurred in the combustor bed, affecting mixing efficiency with direct reduction in the combustion efficiency.

NOTE: Quality assurance of data may not be appropriate for all uses.

Other problems occurred with the stack sampling method. During one stack sampling sequence, fly ash was inadvertently dispersed throughout the operating bay, resulting in the evacuation of the entire office/pilot plant building. Siloxanes were present in the stack gas stream and interfered in the laboratory procedures to analyze the stack gas samples. However, the siloxanes may have been from silicone sealant which was used to install an in-line oxygen monitor, or from silicone rubber sealants in the sampling trains or similar sources. The demonstration trial runs and the supplementary tests indicated that the formation of agglomerates affected the combustion efficiency of the CBC unit, and increased the emission of products of incomplete combustion (PICs).

CONTAMINANTS:

Analytical data is provided in the treatability study report. The breakdown of the contaminants by treatability group is:

Treatability Group	CAS Number	Contaminants
W01-Halogenated Aromatic Compounds	TOT-TCB	Total Trichlorobenzenes
W02-Dioxins/Furans/PCBs	11096-82-5	PCB 1260
	12672-29-6	PCB-1248

980-TSI-RT-EUXM

EVALUATION REPORT

GA TECHNOLOGIES, INC.
PCB DESTRUCTION FACILITY
CIRCULATING BED COMBUSTOR
DEMONSTRATION TRIALS FOR NATIONWIDE PERMIT

by
Hiroshi A. Dodohara
20 DECEMBER 1985

GA TECHNOLOGIES INC. DEMONSTRATION TEST RESULTS

SUMMARY

Background: GA Technologies, Incorporated submitted an application to obtain a PCB disposal operating permit for the Circulating Bed Combustor (CBC), an incinerator using fuidized bed technology. The CBC was demonstrated for approval May 20 through May 29, 1985. As a non-liquid PCB incinerator, the CBC was demonstrated with spiked soil of 10,000 ppm PCB concentration at a feed rate of 400 pounds per hour. The combustion temperature was 1800°F. Three four-hour runs were completed, however, because problems occurred in the sampling of particulates in the initial test, a fourth abbreviated run of two hours was conducted solely for collecting a particulates sample. Split samples of feed soil, fly ash, and bed ash were taken and analyzed. Stack emissions samples were collected using the Modified Method 5 (MM5) for particulates and for semi-volatile organics and the Volatile Organics Sampling Train (VOST) for volatile organics. Quality assurance check samples were also submitted to Analytical Technologies Incorporated during the laboratory audit.

In addition to the four demonstration tests, three supplementary runs were conducted to evaluate low combustion temperatures and to incinerate PCB-contaminated site soil.

Test Results: Performance standards for non-liquid PCB incinerators exclude the criteria for combustion temperatures, residence time and excewss oxygen. All other PCB incinerator standards are applicable. The quality assurance audit of the laboratory indicated adequate performance. Test results are summarized in Table A. One test run resulted in low combustion efficiency (99.82% vs. 99.9% standard). The low combustion efficency however, did not affect the destruction and removal efficiency (DRE). All DREs were above the six 9s criteria for

PCBs incinerators. No significant PCBs stack emissions were indicated. Particulates stack emission during one test did not meet the standards for stationary air point sources of 0.08 grains/dry standard cubic feet (gr/dscf). Test run 4 resulted in a particulates emission of 0.095 gr/dscf. The high particulates emission was attributed to a high process air supply inadvertently applied to the air bag filtration unit. The other test value of significance is the residual dioxin and furan in the treated soil. High values of 1.33 ppb for dioxins and furans were indicated in the fly ash. The Center for Disease Control indicated a safe value in soil to be 1 ppb for 2,3,7,8 TCDD.

Two items remain incomplete. One is the PCBs analysis from solvent extracts of the particulate filter media. The second item is the calibration of the chloride in-line monitoring instrument using a two-feet section tubing and also using a 25 feet tubing section. Values for the two tests will be compared to determine whether or not significant differences exists between the two method. The comparison will be made in order to resolve the departures from standard chloride sampling techniques.

CONCLUSION

Evaluation of test results for both the demonstration trial runs and the supplementary tests indicate that the formation of agglomerates has some effect on the combustion efficiency of the CBC unit. DREs were not affected significantly although Combustion Efficiency standard of 99.9% was not met in one of the demonstration test and in al of the supplementary runs. Indications are that agglomerate formation also increases the emissions of products of inclomplete combustion (PICs). In one of the supplementary runs, significant concentrations of phthlates were noted in the stack emissions.

RECOMMENDATIONS

Approval for the GA Technologies, Inc. CBC unit to operate does not impose unreasonable risk to health and environment when operated as intended. Therefore, strict operating restrictions must be imposed to assure proper operation of the CBC.

The following provisions in addition to the non-liquid PCB incinerator performance standards should be included as conditions of approval to ensure proper operation of the CBC:

1. Operating temperature: 1750 - 1850 °F.
2. Process air supply to Bag House: as recommended by manufacturer.
3. Frequent inspection of the Bag House air supply.
4. Shutdown of the CBC when the Combustion Efficiency falls below the 99.9% standard, when the Combustion Efficiency cannot be brought up to standard after a speciied period of time, say one hour.
5. Pneumatic transfer system for soil feed should be modified.

TABLE A
GA TECHNOLOGIES DEMONSTRATION TEST RESULTS (TESTS 1 THRU 4)

TEST PARAMETER	RANGE	STANDARD (Reg)	COMMENTS
TEST TEMPERATURE °F	1,795-1,815°F	2,191°F for PCB incinerator	standard not applicable for non-liquid incinerator
COMBUSTION EFFICIENCY, %	99.82 - 99.97	99.9 MIN. (§761.70)	99.82 C.E. caused by formation of agglomerates in combustion bed
DESTRUCTION REMOVAL EFF. %	99.9999	99.9999 MIN. (§761.70)	low combustion efficency did not affect DRE
PCBs, g_{out}/kg_{in}	0.000045 - 0.00023	0.001 gm out/kg PCB introduced (§761.70)	
Dioxin, ug/m^3	<0.0092 - <0.029	No current emissions standards	Not detected at detection limits
Furans, ug/m^3	<0.0027 - <0.015	No current emissions standards	Not detected at detection limits
Trichloro-benzene, ug/m^3	0.28 - 0.29		
Particulates, gr/dscf	0.0024 - 0.0950	0.08 gr/dscf	0.095 gr/dscf result attributed to high process air pressure
Carbon Monoxide, ppm	22 - 105	200,000 ferroally production (§60.263) 500 petroleum refinery (§103)	
Hydrogen Chloride, ppm)	57 - 266	min. of 1% HCl entering system if over 4 lb/hr HCl discharged	highest emission rate was 0.7 lb/hr
Nitrogen Oxides, lb/MBtu	0.035 - 0.156	0.2 lb/M Btu, steam generation most stringent	
Volatile Organics	No significant emissions	Benzene & vinyl chloride controlled at NESHAP	All V.O. emissions compared well OSHA PELs, all under limits
Semi-Volatile Organics	Siloxanes, phthalates significant emissions	No current standards	Phthalates above OSHA PEL limit, no PEL for siloxanes
Ash Residues	PCDDS, PCDFs <0.25 - <1.33	No current standards	Not detected at detection limits, 1 ppb dioxin considered safe by CDC

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GA TECHNOLOGIES, INC.

DEMONSTRATION TRIALS FOR NATIONWIDE PERMIT

EVALUATION REPORT

BACKGROUND

The demonstration trials were conducted to obtain an EPA nationwide permit to operate the PCB destruction facility, a transportable 16" diameter unit located in La Jolla, California. The data generated will be used to design a 36" transportable commercial facility to treat PCB-contaminated soil at a site in Berkeley Heights, New Jersey owned by Gulf Oil Corporation, a subsidivision of Chevron Corporation. Gulf Oil has been working with the New Jersey Department of Environmental Protection (DEP) to quantify the extent of contamination and to determine the best method to clean the site. Some portions of the Berkely Heights site were found to contain as much as 6000 ppm PCBs.

The New Jersey DEP has recently imposed extensive study requirements in the form of a 50 feet by 50 feet sampling grid to gather subsoil data. Consequently Chevron has shifted emphasis to initiate the commercial use of the CBC from the New Jersey location to a PCB-contaminated site in Alaska.

GA Technologies demonstrated the Circulating Bed Combustor (CBC) shown in Figures 1 and 2 for disposal of PCB-contaminated soil spiked to 10,000 ppm PCB concentration. The CBC uses high turbulence, low temperatures and recirculating solids to destroy PCBs. GA claims high turbulence ensures good contact between the waste and both incoming air and recirculating hot solids which rapidly heats the waste to combustion temperature while in the presence of excess air. Combustion takes place along the entire height of the combustion chamber. Solids are separated from off-gases by an integral cyclone and returned to the combustor through a nonmenchanical seal. Temperatures are uniform, within ±50°F, throughout the loop. The entire unit operates slightly below atmospheric pressure to preclude fugitive emissions. As an alternate to a wet scrubbing sytem, limestone is fed into the combustor primarily to neutralize and to reduce HCl and other acidic gases in the stack gases. A flow diagram illustrates the process in Figure 3.

Demonstration Trials: The demonstration trials were conducted during the period from May 24 through May 29, 1985. Three runs each of four-hour duration were required to fulfill conditions of the demonstration permit. However, four test runs were completed, the fourth run being of two-hour duration solely to collect a particulates sample to satisfy all sampling requirements for Test 1. The particulates sampling filter paper became dislodged during Test 1 nullifying the sample and necessitating a fourth make-up test run.

Three additional test runs were completed after the demonstration trials. One test (Test 5) was conducted at a lower combustion temperature with the spiked soil and the other two tests (Tests 6 & 7) were conducted feeding site soil from Berkeley Heights. Although these last three tests were not part of the PCB disposal demonstration, data from these tests are included to provide additional information.

The demonstration tests were auditted by Team Leader Jared Flood and Chemical Engineer Hiroshi Dodohara of the PCB Disposal Section of Chemical Regulation Branch, Office of Toxic Substances. Gary Kelso and Fred Bergman of Midwest Research Institute coordinated the sampling of solids streams and the sampling of stack emissions, respectively. The laboratory audit was performed by John Smith of Design Development Branch, Office of Toxic Substances.

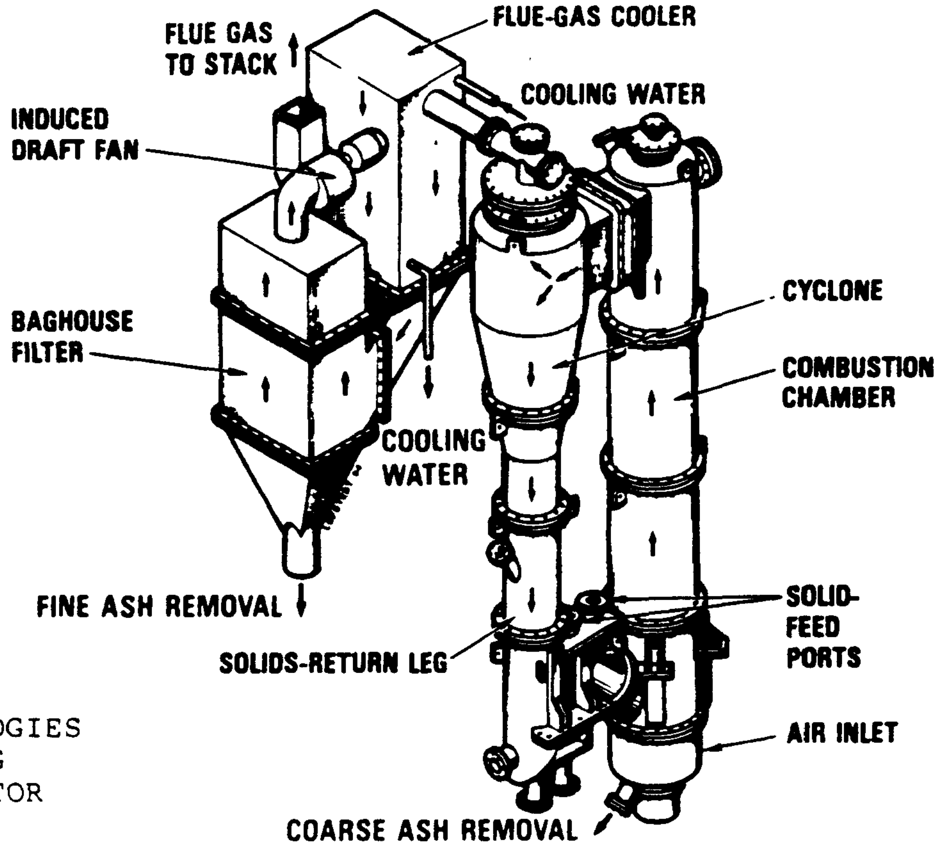

FIGURE 1.
GA TECHNOLOGIES
CIRCULATING
BED COMBUSTOR

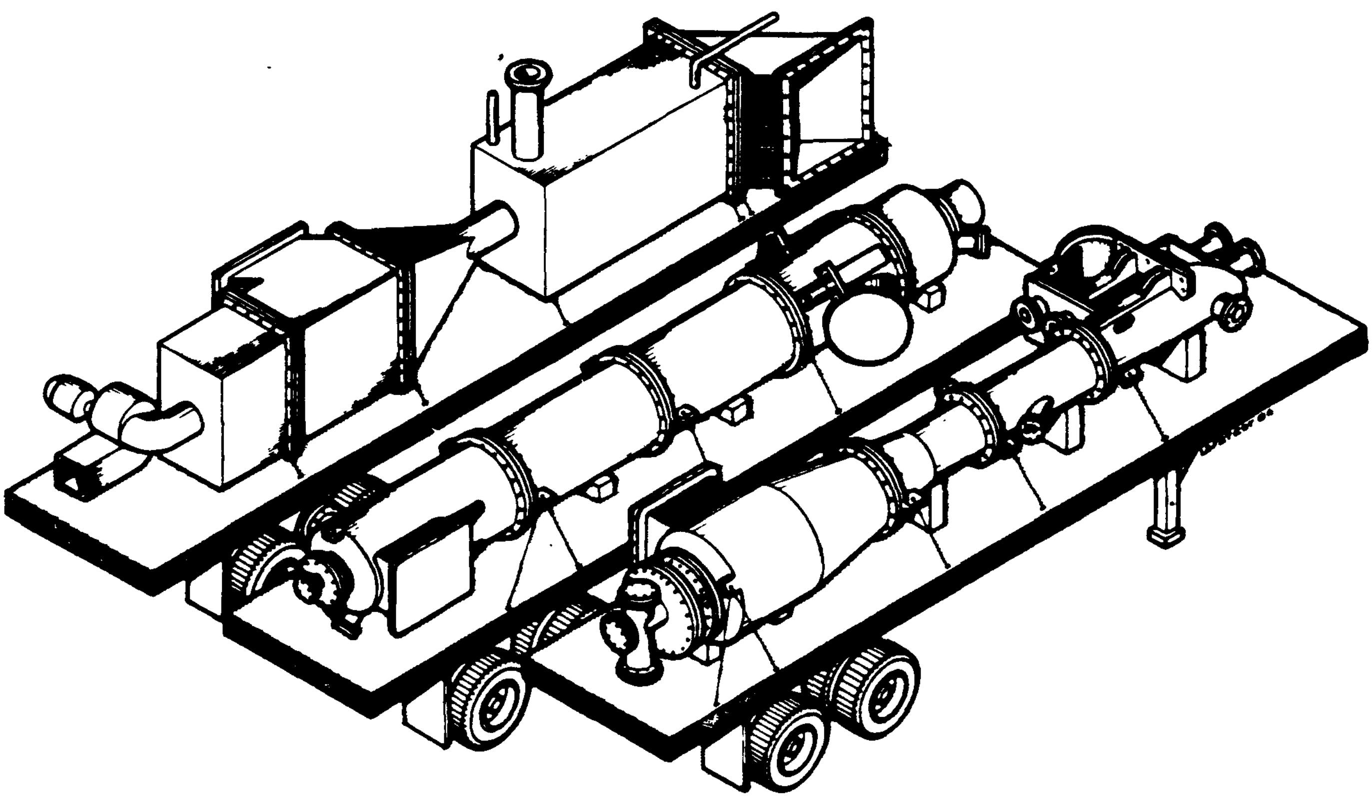

FIGURE 2. GA CIRCULATING BED CUMBUSTOR TRANSPORTABLE CONCEPT

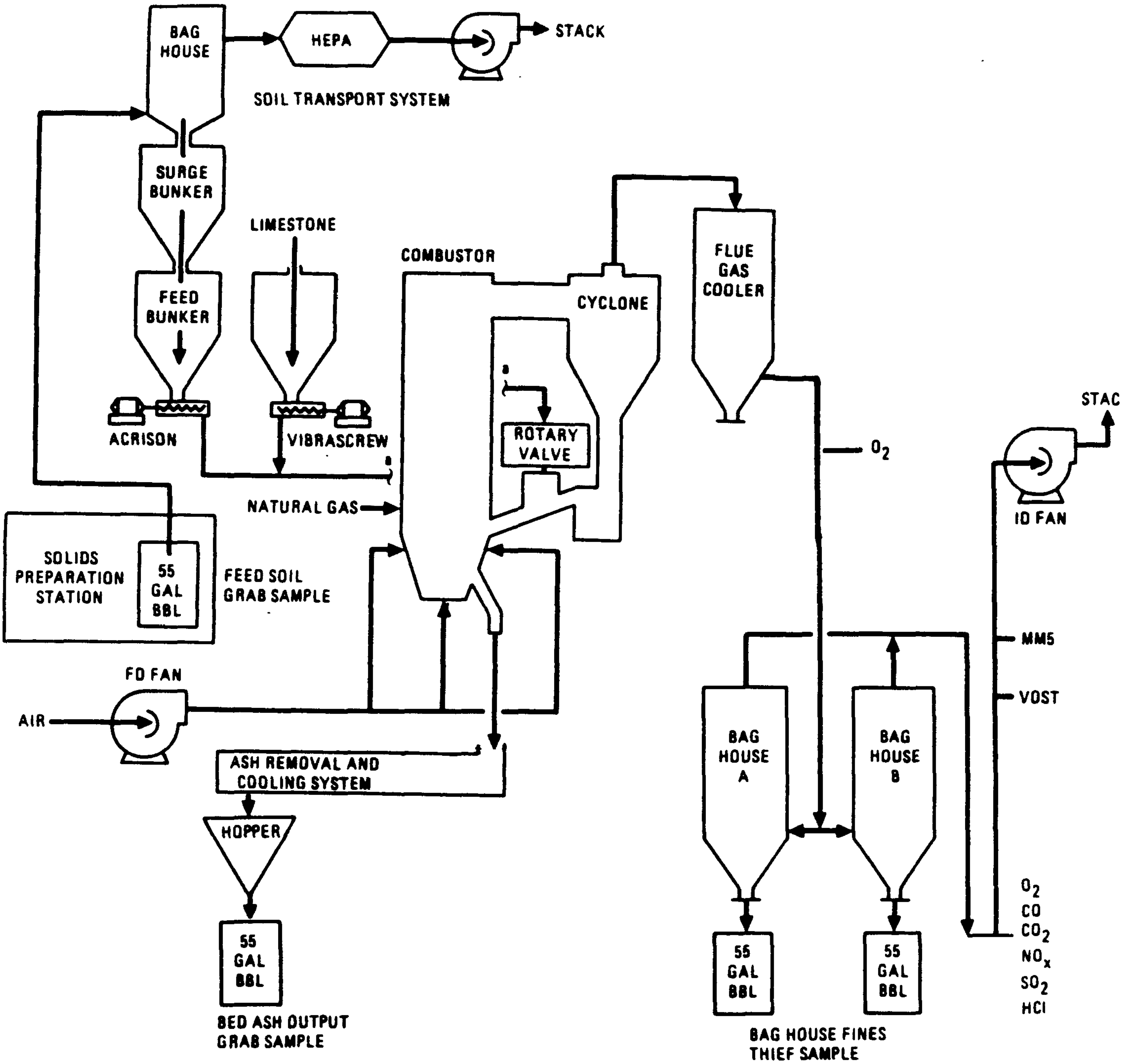

FIGURE 3 GA CIRCULATIONG BED COMBUSTOR FLOW DIAGRAM

OPERATIONAL PROBLEMS

Combustion Bed Agglomerates: Agglomeration of soil in the combustor bed affected mixing efficiency with direct reduction in the combustion efficiency (CE). Cause of the agglomeration was attributed to power failure from electrical circuit breakers which resulted in flame-out (extinguishment of burner flame). The process upset caused by the flame-out ultimately resulted in hot spots along the combustor system which contributed to the formation of agglomerates.

Negative Stack Pressure Sampling: The stack sampling contractor had no experience in the sampling of stacks under small vacuum pressures. Most stacks are under positive pressures or at atmospheric pressures. In one sampling sequence as the sampling instrument was being replaced, a pressure pulse directed back to the baghouse filters caused fly ash to disperse throughout the operating bay resulting in the evacuation of the entire office/pilot plant building. Wipe test analysis were performed after clean-up and prior to resumption of operations.

Modified Method 5 Sampling: The sampling contractor had no prior experience in the Modified Method 5 (MM5) sampling technique. They received much guidance from the EPA consultant (Fred Bergman of MRI) during the course of operation. Their inexperience caused much delay in start-up of the demonstration tests.

The MM5 sampling train is equipped with an impinger to collect chloride emissions. The impinger normally contains caustic solution to absorb the chlorides. For the purpose of this demonstration, mercuric chloride was substituted for the caustic solution.

Siloxane Interference in Stack Emission Analysis: Use of silcone sealant to install an in-line oxygen monitor at a more advanatageous location apparently caused siloxanes to enter the stack gas stream and ultimately interfered in the laboratory procedures and analysis of the stack gas samples. However, the silicone sealant was not confirmed to be the source of the siloxanes. Silicone rubber sealants in the sampling trains or other similar sources may have been the problem.

Pneumatic Transfer System: The soil pneumatic feed transfer system was designed for handling high density, uniform radionuclear particles with right angle bends throughout the unit. The damp, irregularly shaped soil fed during the trials were not ideal for the pneumatic transfer system. Periodic clogging of the transfer ducts caused difficulties during the processing; however, the disposal operations were not affected. Field CBC units to be constructed in the future will likely not incorporate pneumatic feed systems.

TEST RESULTS

Test results were submitted to EPA on September 4, 1985. Quality assurance (QA) results for the laboratory were not available until December 2, 1985. The QA audit indicated adequate performance by Advanced Technologies, Incorporated of National City, California. These results demonstrated that the GA Technologies CBC incinerator is capable of destroying non-liquid PCB as required by 40 CFR 761.70(b)(1) and (2). Results from triplicate tests indicated less than one part per million (ppm) PCBs in both the bottom ash and the fly ash. Stack gas samples revealed less than the emission standard of 0.001 gram of PCB emitted per kilogram of PCB introduced into non-liquid PCB incinerators.

Tables 1 through 4 summarize results of the seven tests runs including DREs, combustion efficiencies, and stack emissions. Tables 5 through 8 tabulates available results from all test runs. A discussion of performance parameters by item follows.

Combustion Temperature, Residence Time, and Excess Oxygen: PCB incinerator performance standards pursuant to 40 CFR 761.70(a)(1) for combustion temperatures, residence time, and excess oxygen do not apply to non-liquid PCB incinerator.

Combustion Efficiencies: PCB rules require a combustion efficiency of 99.9% for non-liquid PCB incinerators. Tests 1, 2 and 3 meet this standard. However, Tests 4 through 7 fell short of the 99.9% requirement.

	Test Nos.						
Combustion	1	2	3	4	5	6	7
Efficiency	99.94	99.95	99.97	99.82	99.67	99.80	99.85

According to GA Technology representatives the lower combustion efficiencies obtained in Tests 4 through 7 resulted from the formation of agglomerates in the combustor bed. The agglomerates reduced the mixing efficiency of the combustor bed resulting in higher carbon monoxide levels than usual and lower combustion efficiencies. Agglomerates were formed initially during Test 3 when power failures resulted from a faulty circuit breaker. Temperature excursions as high as 1900°F and above occured which potentially causing the agglomerate formation. On completion of Test 3 the CBC was shutdown for the long Veterans Day weekend. The following short work week imposed some time constraints, because four tests were scheduled during the folowing four days. With a tight schedule to complete, the CBC was not cleaned out properly and the formation of agglomerates seemingly worsened thoughout Tests 4 through 7 with accompanying low combustion efficincies.

DREs: Except for Test 7, DREs for all tests were within the PCB incinerator criteria of 99.9999% (six 9s). Tests 6 and 7 initially indicated DREs of 99.999% and 99.995 respectively.

PCB DESTRUCTION TEST RESULTS

TABLE 1
COMBUSTION EFFICIENCY, DESTRUCTION
AND REMOVAL EFFICIENCY (DRE), AND STACK EMISSIONS

TEST NO.	TEST TEMPERATURE, °F	COMB. EFF. %	DRE %	CO ppm	HCl ppm	NO_x ppm
1	1,805	99.94	> 99.9999	35	57	25.7
2	1,805	99.95	> 99.9999	28	202	24.8
3	1,795	99.97	> 99.9999	22	255	76.1
4	1,815	99.82(a)	(b)	105	266	22.3
5	1,625	99.67(a)	> 99.9999	119	266	22.9
6	1,795	99.80(a)	99.999 (> 99.9999) (c)	124	55	55.4
7	1,805	99.85	99.995(a) (> 99.9995) (c)	72	29	18.1

TABLE 2
POLLUTANTS IN STACK EMISSIONS

TEST NO.	PCB ug/m^3(f)	DIOXIN ug/m^3	FURANS ug/m^3	TCB ug/m^3	PARTICULATES gr/dscf
1	0.087	(d)	(d)	< 0.28	See Test 4
2	0.49	< 0.0092	< 0.0027	< 0.28	0.0425
3	0.40	< 0.029	< 0.015	< 0.29	0.0024
4	(b)	(b)	(b)	(b)	0.0950(e)
5	0.038	< 0.0049	< 0.0032	1,500(f)	0.0171
6	0.031	< 0.0093	< 0.0029	3,890	0.0219
7	0.31	< 0.0019	< 0.0016	1,160(f)	0.0053

(a) Did no meet PCB incinerator standard of 99.9 %
(b) Data not requested, test for particulates only
(c) Based on calculated W_{in} derived from chloride mass balance
(d) Data not obtained, interference from silicones in analysis
(e) Did not meet particulates standard for RCRA and CAA incinerators of 0.08 gr/dscf
(f) $\frac{ug}{m^3}$ is roughly equivalent to ppb, can convert by multiplying by $\frac{24.8}{\text{mol. wt.}}$

However, when back-calculated for DRE using mass balance for chlorides, the DREs were 99.9999% and 99.9995%.

DREs for Test Nos.						
1	2	3	4	5	6	7
99.9999	99.9999	99.9999	*	99.9999	[99.9999]	[99.9995]

* Test was conducted for particulates sampling only, DRE was not required.

[#] Calculated by use of chloride mass balance.

The apparent low DREs for Tests 6 and 7 were caused by cross-contamination of PCBs from spiked soil having the high PCB level of 10,000 ppm. Feed material for Tests 6 and 7 were site soil from Berkely Heights with low PCB levels of 20 ppm and 47 ppm respectively. Residual soil high in PCB in the feed system from previous tests cross-fed into CBC with soil of low PCB levels in Tests 6 and 7. The higher DREs of 99.9999% and 99.9995% were calculated by summing up inorganic and organic chlorides in the feedstock and in discharges, and then compensating for the additional chlorides introduced into the CBC combustor by the residual soil from previous runs.

Carbon Monoxide, CO: Although standards for carbon monoxide emissions do not exist for incinerators, limits are promulgated for ferroalloy production facilities (40 CFR 60.263) of 20% or by volume or 200,000 ppm of carbon monoxide and for petroleum refineries (40 CFR 103) of 0.05% by volume or 500 ppm carbon monoxide. The highest concentration of carbon monoxide discharged during the CBC demonstration was 124 ppm CO in Test 6.

	Test No.						
	1	2	3	4	5	6	7
CO, ppm	35	28	22	105	119	124	72

Hydrogen Chloride, HCl: Performance standard for RCRA (40 CFR 340) and CAA (40 CFR 61) incinerators is the larger value of hydrogen chloride discharged at rates of four (4) pounds per hour or at rates of one per cent of the chorides entering the pollution control equipment. The highest HCl emission rate was for Test 4 with a stack rate of 550 dscf/min of gas containing 266 ppm HCl. This rate is equivalent to an emission rate of about 0.7 lb/hr of hydrogen chloride, well below the standard for discharges of HCl.

	Test No.						
	1	2	3	4	5	6	7
HCl, ppm	57	202	225	266	266	55	29

Nitrogen Oxide, NO_x: No nitrogen dioxide emission standards exists for incinerators; however, standards do exist for steam and electric utility steam generating units.The highest NO_x emission was 0.156 lb NO_x /MBtu (based on a molecular of 38 grams/gram molecular weight, as an average of predominant species NO_2 and NO), as seen below:

TEST NO.	1	2	3	4	5	6	7
NO_x, ppm	25.7	24.8	76.1	22.3	22.9	55.4	18.1
NO_x, lb/MBtu	0.037	0.036	0.156	0.035	0.036	0.086	0.028

The most stringent standards are those for gaseous fuel at 86 nanograms NO_x/Joule or 0.2 pounds NO_x/million Btu of heat input. These standards are based on quantity of nitrogen dioxide per power rating or heat input rating and are presented at 40CFR 60.40 and 40a as:

§60.40 Steam Generating Units of 73 Megawatts or 250 million Btu/hour input or more

	NO_x Emission Standard	
FUEL TYPE	ng/Joule	lb/M Btu
Gaseous fuel with or without wood residue	86	0.20

PICs[a]

TABLE 3 VOLATILE ORGANICS:[c] VOST RESULTS[b]

ORGANICS	ORGANICS CONCENTRATIONS, ug/m³ [c]					
	TEST 1	TEST 2	TEST 3	TEST 5	TEST 6	TEST 7
Benzene	>293.68	>389.8	>214.6	38.72	49.84	39.3
Bromomethane	-	-	9.02	-	-	-
2-butanone	-	-	-	-	-	6.48
Chloroethane	27.65	30.10	4.47	-	-	-
Choroform	>262.8	>1,506.	>719.9	0.43	>82.54	2.93
Chloromethane	17.14	31.74	>1,221.	4.92	29.14	2.28
Ethylbenzene	-	-	35.62	-	0.43	1.31
Tetrahydrofuran	-	-	2.13	2.20	-	0.71
Toluene	7.20	3.58	1.86	5.02	6.87	7.53
Total Xylenes	0.96	-	-	1.82	7.31	8.18
1,1,1 Trichloroethane	-	0.42	11.2	-	6.31	-
Trichlorothene	0.43	-	0.39	0.26	-	0.82
Vinyl Chloride	-	5.17	-	-	-	-
Alkanes	0.43	-	90.96	0.21	1.77	-
Alkenes	20.04	9.53	57.78	6.42	12.22	8.40
Alkyl furans	12.55	3.36	3.23	-	-	-
Aldehydes	0.49	-	29.66	0.24	0.23	0.49
Silanes	224.37	217.9	232.57	192.4	129.9	667.9

(a) PICs = Products of Incomplete Combustion
(b) Volatile Organic Sampling Train
(c) Each result is an average of 6 sample analyses taken during the test.

PICs[a]

TABLE 4 SEMI- VOLATILE ORGANICS: MM5 RESULTS[b]

ORGANICS	ORGANICS CONCENTRATIONS, ug/m^3					
	TEST 1	TEST 2	TEST 3	TEST 5	TEST 6	TEST 7
Acyclic Hydrocarbons	-	-	-	9,165	23,571	24,645
Aldehyde/ketone	30.24	1.87	38,257	1,887	-	-
Carbon acids/bases	58.25	79.57	11,065	-	14,246	11,618
1,2,4-Trichlorobenzene	-	-	1,536	3,885	1,162	-
Chlorinated hydrocarbon	19.21	-	-	-	-	-
Phenol	-	19.21	52.71	-	6,994	2,817
Phthalates	63.8	24.70	-	-	56,986	10,738
Siloxanes	99.86	85.06	56,200	2,156	36,264	4,577

(a) PICs = Products of Incomplete Combustion
(b) EPA Modified Method 5, a sampling train for particulates with an addition of an XAD resin cartridge for semi-volatile organic sampling

cont'd

FUEL TYPE	NO_x Emission Standard	
	ng/Joule	lb/M Btu
Liquid fossil fuel with or without wood residue	130	0.30
Solid fossil fuel with or without wood residue	300	0.70

§60.40a Electric Utility Steam Generating Units of 73 Megawatts or 250 Btu/hour input or more

FUEL TYPE	NO_x Emission Standard	
	ng/Joule	lb/M Btu
Gaseous fuel (Coal derived)	210	0.50
All others	86	0.20
Liquid fuel (Coal derived)	210	0.50
Shale oil	210	0.50
All others	130	0.30
Solid Fuel	210	0.50

<u>Particulates:</u> Emission standards for RCRA and CAA incinerators (40 CFR 264.340 and 40 CFR 60) limit the discharge of particulates to 0.08 gr/dscf. Test 4 discharged particulates above the standards (0.095 gr/dscf). This condition was attributed to process air pressure to the baghouse filter above that recommended by the manufacturer. The high pressure apparently stretched the filter media allowing higher than normal particulates to pass through the media.

	Test No.						
	1	2	3	4	5	6	7
Particulates, gr/dscf	*	0.0425	0.0024	0.0950	0.0171	0.0219	0.0053

* See Test 4 results

<u>PCB Emissions:</u> For non-liquid PCB incinerators, the emission standard is 0.001 g PCB/kg PCB introduced into the incinerator. All tests except for Test 7, complied with this critical standard. PCB stack emissions for the GA CBC unit were:

TEST NO.	PCB Emissions grams PCBs out/kg PCBs Introduced
1	0.000045
2	0.00019
3	0.00023
4	sample not required
5	0.000017
6	0.00022*
7	0.0046*

* Calculated from chloride mass balance

In the laboratory analysis of PCBs, rinseate from the cleaning of the MM5 probe was not analyzed for PCBs. Likewise, the particulates collection samples were not extracted for residual PCBs. Fred Bergman of MRI indicates that up to 80 percent of the total quantity of PCBs may reside in the probe and in the particulates and particulates filter media. Assuming two values, 50% and 80%, of the total PCBs to be remaining in the probe and particulates system, the DREs were recalculated. Table 9 indicates that at the 50% level, all but Run 7 met the six 9s criteria (using the chloride mass balance results). At the 80% level, all tests treating spiked soil (10,000 ppm PCBs) met the six 9s criteria. One run with the site soil feed passed the six 9s criteria and the second failed (using the chloride mass balance results).

Dioxins and Furans: No dioxins or furans were detected at the detectable levels indicated, the highest detectable concentrations of dioxins and furans in the stack emission was 0.029 ug/m^3 (see Table 2). Although emission standards do not exist for dioxins and furans, a DRE of six 9s for the destruction of PCBs Arochlor 1260 meets with conditions for incinerators burning designated dioxin-containing waste under RCRA rule 40 CFR 264.343. The incinerator must meet the six 9s DRE for the principal POHCs, in this case Arochlor 1260, which are more difficult to burn than tetra- , penta-, and hexachorodibenzodioxins and furans. The measure of cumbustion difficulty is the heat of combustion, the lower heat of combustion indicating a higher degree of combustion difficulty. A comparison is presented below.

Dioxins	Heat of Combustion Kcal/gm	Furans	Heat of Combustion Kcal/gm	Arochlor 1260 (Composition)	Heat of Combustion Kcal/gm
Tetra	3.46	Tetra	3.65	Penta (12%)	3.65
Penta	3.10	Penta	3.40	Hexa (38%)	3.25
Hexa	2.81	Hexa	3.07	Hepta (41%)	2.98
				Octa (8%)	2.72

Although the PCB-spiked soil is not one of the RCRA designated dioxin-containing waste, the capability to meet the performance standards has certainly been demonstrated.

The concentrations of dioxin and furan residues in the fly ash and the bed ash did not exceed 1.33 ppb (highest detectable levels) for Tests 1, 2 and 3 (see Tables 6 and 8). Dioxin and furan concentrations were no higher than 3.8 ppb for Tests 5, 6, and 7, (highest dectable levels) indicating that the lower Combustion Efficiency in these tests had a noticeable effect on ash content for these organics. Soil contaminants lower than 1 ppb dioxins** is considered by the Center for Disease Control to be environmentally safe.

** Conversation with D. Keehner, Chief, Reg. Sect. CRB/EED/OTS 12-12-85.

PICs: Products of incomplete combustion (PICs) are listed in Tables 3 and 4 as Volatile and Semi-volatile organics. Dioxins and furans were previously discussed. Tables 10 and 11 tabulates the high emission values for the volatile and semi-volatile organics detected in the stack emissions samples. All but two of the organics are currently not regulated under the Clean Air Act. Benzene and vinyl chloride are controlled via the National Emissions Standard for Hazardous Air Pollutanta (NESHAP). Benzene is regulated under the Equipment Leak provisions of NESHAP which controls fugitive emissions. Equipment is required to operate at a 500 ppm above background level. Leaks are defined as detections of 10,000 ppm or greater of vapors at the equipment, and are required to be repaired within five days. Vinyl chloride has an emission standard of 10 ppm under NESHAP.

With the need for a benchmark to compare the emission levels of stack gases and vapors, the OSHA standards for worker exposure level to each organic chemical was used. The standards listed in Tables 10 and 11 represent time-weighted averages (TWA) of permissible exposure level (PEL) to the organic vapors for a worker during an eight-hour work shift. Comparison of the Volatile Organics emissions to PEL values reveal that they are generally well below the OSHA standards. The Semi-Volatile Organic emissions for Tests 1, 2, and 3 are again generally below the PEL levels; however, emissions for Tests 5, 6, and 7 indicate a tendency for higher levels of Semi-Volatile Organics. Carbon acids and bases with an emission value of 14.25 mg/m^3 is greater than the PEL value of 12 mg/m^3. Phthalates emissions were 57 mg/m^3 and compares poorly with a PEL of 5 mg/m^3. Low combustion efficiencies attained during Tests 5, 6, and 7 may have resulted in higher values of Semi-Volatile Organics.

k. Ash Residues: The ashes from the CBC incinerator were predominantly treated soil. Bed ash is discharged from the CBC combustion chamber and fly ash results from treatment of the flue gas by the baghouse filters. In all cases, the PCB levels were below the concentration necessary for designating the treated soil as non-regulated for PCBs (2ppm or 2,000 ppb per congener). Dioxins and furans were not detected at those detectable limits designated.

Ash residues containing dioxins and furans in the range from 0.27 to 1.28 ppb from a RCRA incinerator were proposed for delisting as a hazardous waste (FR 50 23721-23728, June 5, 1985).

	Test No.						
	1	2	3	4	5	6	7
Bed Ash							
PCBs, ppb	3.49	33.27	185.9	*	5.3	71.75	314.8
Dioxins, ppb	<0.37	<1.22	<1.23	*	<3.8	<1.83	<1.89
Furans, ppb	<0.25	<0.85	<1.33	*	<1.88	<1.21	<1.50
Fly Ash							
PCBs, ppb	66.45	9.90	32.12	*	26.81	106.0	55.2
Dioxins, ppb	<0.58	<0.25	<1.33	*	<1.24	<0.84	<3.1
Furans, ppb	<0.72	<0.54	<0.84	*	<1.12	<0.58	<2.8

TABLE 5

GA TECHNOLOGIES, INC.
PCB DEMONSTRATION TEST RESULTS

	TEST 1	TEST 2	TEST 3	TEST 4
Soil Feed Rate, lb/hr	327.5	411.5	323.8	428.0
Total Soil Feed, lb	1,310	1,646	1,295	856
PCB Feed Concentration, ppm	11,000	12,000	9,800	10,000
(MRI results, GC/ECD)	(9,600)	(9,500 & 7,900)	(8,900)	-
(MRI results, GC/MS)	(8,500)	(9,140 & 7,950)	(8,050)	-
PCB Feed Rate, lb/hr (W_{in})	3.65	4.94	3.17	4.28
CO, ppm	35	28	22	105
CO_2, %	6.2	6.0	7.5	5.9
NO_x, ppm	25.7	24.8	76.1	22.3
Combustion Eff. %	99.94	99.95	99.97	99.82
Superficial Velocity, ft/sec	18.7	18.7	18.1	17.6
Residence Time, sec	1.18	1.18	1.22	1.25
Destruction Temp. °F	1,805	1,805	1,795	1,815
Excess O_2, %	7.9	6.8	6.8	6.2
Stack HCl, ppm	57	202	255	266
Stack Gas Flow Rate, dscf/min	504	509	486	550
PCB Output Rate, lb/hr (W_{out})	1.65E-7	9.45E-7	7.22E-7	N/R
DRE, %	> 99.9999	> 99.9999	> 99.9999	N/R
Particulates Concentrations				
Dry, gr/dscf	see Test 4	0.0425	0.0024	0.0950
Wet, gr/acf	see Test 4	0.0227	0.0013	0.0551

N/R = not required, Test 4 only for particulates

$$\text{Combustion Efficiency} = \frac{CO_2}{CO_2 + CO} \times 100$$

$$\text{Destruction Removal Efficiency (DRE)} = \frac{W_{in} - W_{out}}{W_{in}} \times 100$$

TABLE 6

GA TECHNOLOGIES, INC.
DEMONSTRATION TEST RESULTS

PCBs CONCENTRATIONS[a]

TEST NO.	TEMP °F	FEED[b] ppm	BED ASH ppb	FLY ASH ppb	DRE %	STACK GAS CONC.(ug/m^3)
1	1,800	11,000	3.49	66.45	> 99.9999	0.087
2	1,800	12,000	33.27	9.90	> 99.9999	0.49
3	1,800	9,800	185.9	32.12	> 99.9999	0.40
4	1,800	10,000	N/R	N/R	N/R	N/R

DIOXIN CONCENTRATIONS

TEST NO.	FEED ppb	BED ASH ppb	FLY ASH ppb	STACK GAS CONC.(ug/m^3)
1	< 1.55	< 0.37	< 0.58	-
2	< 1.82	< 1.22	< 0.25	0.0092
3	< 12.8	< 1.23	< 1.33	0.029
4	N/R			

FURAN CONCENTRATIONS[c]

1	< 33.8	< 0.25	< 0.72	-
2	< 2.62	< 0.25	0.0092	
3	< 12.8	< 1.23	< 1.33	0.029
4	N/R			

TRICHLOROBENZEN CONCENTRATIONS

1	1,800	< 0.33	< 0.33	< 0.28
2	1,500	< 0.33	< 0.33	< 0.28
3	2,100	< 0.33	< 0.33	< 0.28

(a) = MRI results for bed ash and fly ash are all < 2 ppm by GC/MS method
(b) = PCB 1260
(c) = conservative estimate since no standards were available for hexa-, hepta-, or octabenzofuran

TABLE 7

GA TECHNOLOGIES, INC.
PCB STUDY TEST RESULTS

	TEST 5[a]	TEST 6[a]	TEST 7[a]
Soil Feed Rate, lb/hr	398.0	330.3	285.2
Total Soil Feed, lb	1,592	1,321	1,711
PCB Feed Concentration, ppm	12,000	20	47
PCB Feed Rate, lb/hr (W_{in})	4.78	0.0066	0.00131
CO, ppm	119	124	72
CO_2, ppm	3.6	6.1	4.9
NO_x, ppm	22.9	55.4	18.1
Combustion Eff. %	99.67	99.80	99.85
Superficial Velocity, ft/sec	16.6	19.3	18.6
Residence Time, sec	1.32	1.14	1.18
Destruction Temp. °F	1,625	1,795	1,805
Excess O_2, %	9.7	8.6	8.1
Stack HCl, ppm	266	55	29
Stack Gas Flow Rate, dscf/min	540	540	543
PCB Output Rate, lb/hr (W_{out})	8.02E-8	6.01E-8	6.45E-7
DRE, %	> 99.9999 --	> 99.999 (> 99.9999)(b)	> 99.996 (> 99.9995)(b)
Particulates Concentrations			
Dry, gr/dscf	0.0171	0.0219	0.0053
Wet, gr/acf	0.0100	0.0122	0.0031

(a) Tests 5 and 6 were 4-hour duration; Test 7 was 6-hour duration
(b) Based on calculated W_{in} derived from chloride mass balance

TABLE 8

GA TECHNOLOGIES, INC.
PCB STUDY TEST RESULTS

PCBs CONCENTRATIONS

TEST NO.	TEMP °F	FEED[b] ppm	BED ASH ppb	FLY ASH ppb	DRE %	STACK GAS CONC.(ug/m^3)
5	1,625	12,000[b]	5.3	26.81	> 99.9999	0.038
6	1,800	20[c]	71.75	106.0	> 99.999 (> 99.9999)[d]	0.031
7	1,800	47[e]	314.8	55.2	> 99.995 (> 99.9995)[d]	0.31

DIOXIN CONCENTRATIONS

TEST NO.	FEED ppb	BED ASH ppb	FLY ASH ppb	STACK GAS CONC.(ug/m^3)
5	< 7.42	< 3.8	< 1.24	< 0.0049
6	< 1.97	< 1.83	< 0.84	< 0.0093
7	< 2.13	< 1.89	< 3.1	< 0.0019

FURAN CONCENTRATIONS

5	< 390 [a]	< 1.88	< 1.12	0.0032
6	< 1.27 [a]	< 1.21	< 0.58	0.0029
7	< 1.53 [a]	< 1.50	< 2.8	0.0016

TRICHLOROBENZENE CONCENTRATIONS

5	1,300	< 0.33	< 0.33	1,540
6	< 0.17	< 0.33	< 0.33	3,890
7	< 0.17	< 0.33	< 0.33	1,160

(a) = MRI results for bed ash and fly ash are all < 2 ppm by GC/MS method
(b) = PCB 1260
(c) = PCB 1248
(d) = Values based on chloride mass balance
(e) = Mixture of 6 ppm 1248 and 41 ppm PCB 1260

TABLE 9

DREs ADJUSTED FOR PCB LOSS IN SAMPLING TRAIN

TEST	Win lb/hr	Wout lb/hr	DREs WITH % LOSS IN SAMPLING TRAIN 0%	50%	80%
1	3.60	$1.65X10^{-7}$	99.9999954	99.9999908	99.9999771
2	4.94	$9.45X10^{-7}$	99.9999809	99.9999617	99.9999044
3	3.17	$7.22X10^{-7}$	99.9999772	99.9999545	99.9998861
4	4.28	PCBs samples not required			
5	4.78	$8.02X10^{-8}$	99.9999983	99.9999966	99.9999916
6	0.0066	$6.01X10^{-8}$	99.9990894	99.998178	99.9954468
	[0.28]		[99.9999785]	[99.9999571]	[99.999893]
7	0.0131	$6.45X10^{-7}$	99.9950763	99.9901527	99.9753817
	[0.14]		[99.9995393]	[99.9990786]	[99.9976964]

Win = PCBs fed into CBC with contaminated soil

Wout = PCBs stack emissions

[##] = PCB feed rates and DREs based on chloride mass balance

$$DRE = \frac{Win - Wout/[1 - wt. fraction PCB loss]}{Win} \times 100$$

TABLE 10 POLLUTANT EMISSIONS VS. STANDARDS OR CRITERIA
RUNS 1 THRU 3

VOLATILE ORGANICS

ORGANICS	HIGH EMISSION CONCENTRATION mg/m^3	PEL mg/m^3 (a)	NESHAP(b) STANDARD ug/m^3
Benzene	0.761	32	Equipment Leaks (fugitive emissions); 10,000 ppm defines leaks for pump and valves, must be repaired 500 ppm above background limit fort compressors and closed vent system
Bromomethane	0.033	20(c)(d)	
2-Butanone	-	590	
Chloroethane	0.122	2600	
Chloroform	5.500	240(d)	
Chloromethane	4.135	200	
1,1 Dichloroethene	0.0031		
Ethylbenzene	0.132	435	
Tetrahydrofuran	0.0066	590	
Toluene	0.014	740	
Total Xylenes	-	435(e)	
1,1,1 Trichloroethane	0.027	1900	
Trichlorothene	0.0023		
Vinyl Chloride	0.0064	2.6	10 ppm (26 mg/m^3)
Alkanes	0.246	1,800(f)	
Alkenes	0.656	2,200(g)	
Alkyl furans	0.027	590(h)	
Aldehydes	0.083	3.6(i)	
Silanes	0.660		
SEMI-VOLATILE ORGANICS			
Acyclic Hydrocarbons	-	2,350(j)	
Aldehyde/ketone	38.26	290(k)	
Carbon acids/bases	11.07	12(l)	
1,2,4-Trichlorobenzene	-	40(o)	
Chlorinated hydrocarbon	0.019	10(m)	
Phenol	1.854	19(c)	
Phthalates	0.064	5(n)	
Siloxanes	56.21		

(a) PEL = Permissible Exposure Limit, 8-hr time-weighted average, OSHA Standards, 29 CFR 1910.1000.
(b) NESHAP = National Emission Standards for Hazardous Pollutants
(c) Skin exposure; (d) Ceiling number
PELs for: (e) xylene; (f) propane, hexane; (g) butadiene;
(h) tetrahyrdrofuran; (i) methyl- and isobutylamine; (j) octane;
(k) diisobutyl ketone; (l) methy- and isopropylamine;
(l) hexachloroethane; (n) dimethyl- and dibutylphthalate
(o) Threshold Limit Value (TLV) established 1975, Am. Conference of Gov't. Industrial Hygienists (ACGIH)

TABLE 11 POLLUTANT STANDARDS OR CRITERIA
RUNS 5 THRU 7

ORGANICS	HIGH EMISSION CONCENTRATION mg/m^3	PEL mg/m^3 (a)	NESHAP (b) STANDARD ug/m^3
VOLATILE ORGANICS			
Benzene	0.093	32	Equipment Leaks (Fugitive emissions); 10,000 ppm defines leaks for pumps and valves, must be repaired; 500 ppm above background limit for compressors and closed vent systems
Bromomethane	-	20(c)(d)	
2-Butanone	0.039	590	
Chloroethane	-	2600	
Choroform	4.69	240(d)	
Chloromethane	0.080	200	
Ethylbenzene	0.0079	435	
Tetrahydrofuran	0.006	590	
Toluene	0.019	740	
Total Xylenes	0.033	435(e)	
1,1,1 Trichloroethane	0.027	1900	
Trichlorothene	0.0019		
Vinyl Chloride	-	2.6	10 ppm (26 mg/m^3)
Alkanes	0.071	1,800(f)	
Alkenes	0.027	2,200(g)	
Alkyl furans	-	590(h)	
Aldehydes	0.023	3.6(i)	
Silanes	3.380		
SEMI-VOLATILE ORGANICS			
Acyclic Hydrocarbons	24.65	2,350(j)	
Aldehyde/ketone	3.58	290(k)	
Carbon acids/bases	14.25	12(1)	
1,2,4-Trichlorobenzene	3.89	40(o)	
Chlorinated hydrocarbon	0.019	10(m)	
Phenol	7.00	19(c)	
Phthalates	57.00	5(n)	
Siloxanes	36.27		

(a) PEL = Permissible Exposure Limit, 8-hr time-weighted average, OSHA Standards, 29 CFR1910.1000.
(b) NESHAP = National Emission Standards for Hazardous Pollutants, 40 CFR 61
(c) Skin exposure; (d) Ceiling number
PELs for: (e) xylene; (f) propane, hexane; (g) butadiene;
(h) tetrahyrdrofuran; (i) methyl- and isobutylamine; (j) octane;
(k) diisobutyl ketone; (1) methy- and isopropylamine;
(1) hexachloroethane; (n) dimethyl- and dibutylphthalate
(o) Threshold Limit Value (TLV) established 1975, Am. Conference of Gov't Industrial Hygienists (ACGIH)

PERFORMANCE STANDARDS FOR
NON-LIQUID PCB INCINERATORS

1. 40 CFR 761.70(b)(1) Mass air emissions from the incinerator shall be no greater than 0.001 g PCB/kg of the PCB introduced into the incinerator.

2. 40 CFR 761.70(b)(2) Incinerator shall comply with the following performance standards:

- Incinerator performance standards for temperature and residence time do not apply to non-liquid PCB incinerators
- Combustion efficiency of 99.9%
- Rate and quantity of PCBs fed to the incinerator shall be measured and recorded every 15 minutes
- Incineration temperature measured and recorded continuously
- Stack monitoring shall be conducted when:
    - Incinerator is first used for PCB disposal
    - Incinerator is first used after modification which may alter stack emissions
    - Monitor as a minimum the following:

O_2	CO
CO_2	NO_x
HCl	Total Organic Chlorides
PCBs	Total Particulates

- Continuous monitoring of CO and O_2 and periodic monitoring of CO_2
- Shutdown of PCB feed when:
    - CO, O_2, and CO_2 monitoring system fails
    - PCB feed monitoring systen fails
- Use of water scrubber or alternate to control HCl